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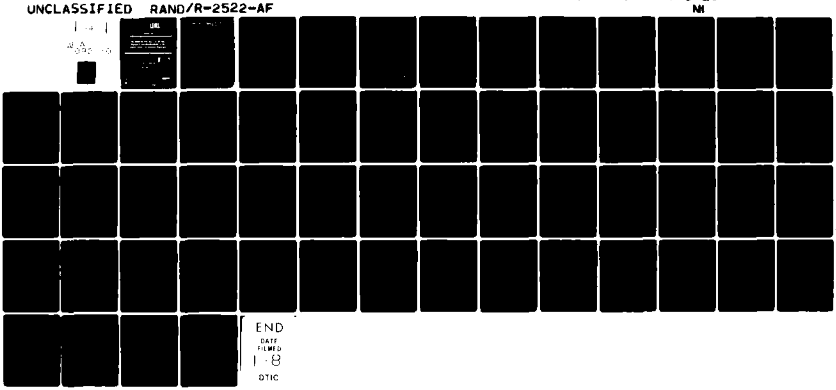

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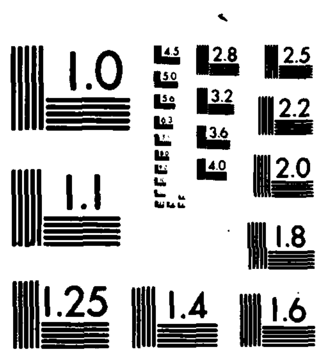


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The Soviet military R&D sector benefits from a wide range of material, administrative, and other priorities, which impose heavy opportunity costs, expecially on civilian R&D. R&D is relatively more expensive in a command economy, so less of it should be used than in a market system. The Soviet use of much less R&D in its military sector is as rational as the American use of much more R&D where R&D is reltively less expensive. If less military R&D is used in the USSR, a measure of its efficiency derived as a ratio of military output to military R&D is biased upward. The relative efficiency of Soviet military output to military R&D is probably much lower than otherwise assumed because input costs are higher and output lower than usually estimated. The arms race is costlier to the Soviet Union than otherwise believed, both absolutely and as an alternative to economic development. 47 pp.

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# The Relative Efficiency of Military Research and Development in the Soviet Union: A Systems Approach

Gur Ofer

A Project AIR FORCE report
prepared for the
United States Air Force



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# PREFACE

This report was prepared as part of the Project AIR FORCE study "Soviet Strategic Competitiveness: Constraints and Opportunities," in close association with the Office of the Assistant Chief of Staff, Intelligence, Hq USAF. The report examines the main factors explaining the apparent high relative efficiency of military research and development (R&D), measured with respect to civilian R&D, in the USSR compared with similar efficiency relationships in the United States and other market economies. It is argued that the relative efficiency of Soviet military R&D is actually much lower than is generally believed in the West.

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## SUMMARY

The secrecy that surrounds all information on Soviet defense spending has helped to perpetuate an apparent inconsistency between Western estimates of Soviet defense budgets on the one hand and the burden of these budgets on Soviet GNP on the other. How could an economy half the size of that of the United States produce at least the same volume of defense goods and services as the United States with a defense burden at approximately the same level? If the GNP estimates are credible, the paradox can be solved in one of three ways: inputs into defense may be underestimated, the output of defense may be overestimated, military production is relatively more efficient than civilian production in the Soviet Union than in the United States.

Although there are proponents of each of the above solutions, much of the debate centers around the issue of the relative efficiency of military and civilian R&D in the Soviet Union compared with those in the United States--the main topic of this report.

The analysis is based on the characteristics and interaction of four pairs of economic sectors, systems, or modes of production: centrally planned or command economy vs. market economy; "regular" production vs. innovational subsystems, civilian vs. military sectors; and within the command economy, regular vs. priority based modes of operations.

The issue of relative efficiency must include an analysis of the situation in the United States. This report, however, emphasizes the Soviet side of the picture. In this respect it can claim to provide only a partial resolution of the puzzle of relative high efficiency of Soviet military (M) R&D.

The complete argument develops as follows:

1. A command economy is ill-fitted to accommodate innovation, and in this respect, it has a comparative disadvantage in relation to a market economy. The discussion of this point is mostly a review of the existing literature molded into the systems approach.

2. From this basic proposition the argument proceeds in two directions: the first is to prove that the actual inputs invested in Soviet MR&D are much larger than conventionally estimated.
   a. Only a system of priorities that goes much beyond mere "resource priority" can create conditions necessary for R&D. By definition, a priority can be extended only to a narrow segment of the economy.
   b. The priority environment extended to MR&D is very expensive in terms of its effects on other sectors of the economy, especially civilian (C) R&D. Such costs, by their very nature, are not directly recorded anywhere. Because priorities cannot generally be extended to other sectors besides the military, they impose a heavy burden of opportunity costs on the rest of the economy.
   c. Although the military sector enjoys some "quasi-natural" advantages conducive to R&D, it also suffers from serious shortcomings. Most of the advantages of MR&D are policy-determined, and they constitute part of the priority system. It is these advantages rather than the "quasi-natural" ones that explain most of the better performance of MR&D. A good part of the debate between the "natural advantage" and "priority" schools is on whether to classify the advantages enjoyed by MR&D as "natural" or as "policy"-determined.
   d. When priority-related costs are added to MR&D budgets, a large part of the efficiency advantages, as calculated by ordinary accounting methods, disappears.
3. The second line of argument derives two implications from point 1 above:
   a. If indeed R&D activity is relatively more expensive in a command economy than a market economy, a rational policy will call for less use of it in any economic activity, including the military sector. It follows that different intensities of R&D activities across economic systems, or

between the United States and the Soviet Union, could be rational for *both* systems or countries and would not necessarily imply that one side or the other behaves uneconomically or is wasting R&D resources.

b. When R&D inputs in the production of, say, defense differ across systems, a measurement of productivity that divides *defense* output by inputs of MR&D is biased, just as the measure of labor productivity is biased when the capital-labor ratio varies. Specifically, it biases upward the efficiency of the party that uses less of the specific input.

The main conclusion of this report is that the relative efficiency of Soviet MR&D is lower, probably much lower, than appears from the paradox presented at the outset or in the view of some students in the field, on two counts: First, the real burden or cost of MR&D is much higher than conventionally estimated; second, the total output of MR&D is lower than previously assumed. When inputs are higher and outputs are lower, estimated efficiency goes down.

A lower relative efficiency in MR&D means that it is more difficult for the Soviet Union to carry on the arms race than otherwise assumed, especially when the race moves into higher spheres of R&D needs. If indeed many of the advantages enjoyed by MR&D are policy determined (and not natural), then they are transferable, at least in principle, to other sectors. This sharpens the tradeoff and choice between the fulfillment of military and civilian goals.

## CONTENTS

## I. INTRODUCTION

The secrecy surrounding all information on Soviet defense spending has helped to perpetuate an apparent inconsistency between Western estimates of Soviet defense budgets and the burden of these budgets on Soviet GNP. How is it that an economy half the size of the U.S. economy managed to produce at least the same volume of defense goods and services as the United States[1] with a defense burden at approximately the same level? If one assumes that the GNP estimates are credible, the paradox can be solved in one of three ways: inputs into defense may be underestimated, the output of defense may be overestimated, or military production is relatively more efficient than civilian production in the Soviet Union than in the United States. A number of observers maintain that the alleged Soviet defense output should be downgraded, because its quality is poorer than assumed by most estimates (Nove, 1971, p. 330; Holzman, 1980, pp. 10-11 ff.). The literature is full of claims that Soviet defense spending is or was underestimated in the West and that when this mistake is corrected, the burden grows and the relative military efficiency declines to more reasonable levels.[2]

Finally, during the late 1960s and early 1970s, many studies emphasized and supported the high *relative* efficiency solution to the paradox. The cost of military personnel is one area of military spending where such claims are usually made--i.e., the Soviet Union pays much less per soldier than the United States although--and this is tacitly assumed--the two soldiers are of similar "quality" (Holzman, 1979, p. 13). Much of the debate centers on the issue of relative efficiency of military R&D (MR&D) to civilian R&D (CR&D) in the Soviet Union and the United States. It may be best represented by a quotation

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[1]For 1976, the CIA estimated Soviet defense activities as 140 percent or 125 percent of that of the United States when compared in dollars and rubles. The corresponding figures for MR&D are apparently even higher. See U.S. Congress, 1977, pp. 22-25; and CIA, 1978, p. 2. See more on this below.

[2]Among others, Lee, 1977; Marshall, 1975. Survey discussions of the issue are included in Hanson, 1978.

from Perry: "One important distinction lies in the evidence that the Soviet military research and development system is markedly more efficient than its civil-sector equivalent, which may well be the reverse of the situation prevailing in the United States" (Perry, 1973, p. v), or from Nancy Nimitz: "It may be that we (Americans) are more efficient at civilian than at military innovation, while the reverse holds for the USSR" (Nimitz, 1980). Other advocates of this approach are Boretsky (1970), and to some extent Alexander (1970, 1978a, 1978b).

The major event in the field of estimating Soviet defense outlays occurred when the CIA revised its own estimates of Soviet defense spending in rubles upward by a factor of two for 1970. According to the CIA, 90 percent of the adjustment reflects revised prices for defense inputs and only 10 percent results from a more exhaustive coverage of defense activities. Thus, at least part of the paradox is solved by raising the ruble cost of defense, by only slightly altering the estimated number of actual weapons produced, etc., thus drastically reducing the estimates of relative military efficiency (U.S. Congress, 1977, p. 17). The estimate for the Soviet burden was also increased from 6-8 to 12-13 percent of Soviet GNP during the 1970s, compared with about 6 percent for the United States. However, if the annual flow of Soviet defense "output" is, let us say, larger by a third than that of the United States, a significant Soviet advantage in relative military efficiency still remains to be explained or disputed, and the debate in the West continues along the same lines.

Although, as stated above, the relative efficiency of Soviet MR&D is a key factor in this debate, the data base is covered by a thick fog. Not only is there greater secrecy surrounding MR&D spending, but there are difficult conceptual problems to resolve in distinguishing between the costs of MR&D--the R&D input--and its output. The CIA apparently also revised upward its estimate of Soviet MR&D outlays. Aware that its basic estimate of this item had been the least satisfactory of all, the CIA did not disclose any details on the basis or justification for the revision (CIA, 1978, p. 3).

The analysis in this report is based on the characteristics and interaction of four pairs of economic sectors, systems, or modes of production: centrally planned or command economy vs. market economy; "regular" production vs. innovational subsystems; civilian vs. military sectors; and finally, within the command economy, regular vs. priority based modes of operations.

The "efficiency paradox" can be formulated as follows: why is Soviet MR&D so much more efficient than CR&D? It is well-known that a command economy is not well suited to accommodate R&D activity; how did the military sector in the Soviet Union manage to overcome these difficulties? Similar questions may be asked about differences between civilian and military efficiency in a market economy or in the United States, to arrive at a final query: How can the ratio of MR&D efficiency to CR&D efficiency be so much higher in the Soviet Union than in the United States? This proposition may be formalized in the following inequality:

$$\left\{\frac{(Q/I)_m}{(Q/I)_c}\right\}_{SU} > \left\{\frac{(Q/I)_m}{(Q/I)_c}\right\}_{US}$$

where Q is R&D output and I its input, and m and c stand for military and civilian. The main problem in this inequality is to estimate Q--the *results* of R&D activity in the various sectors. I do not actually try to estimate Q but only to make a number of observations on its size. Remember that Q cannot be estimated from data on I because such a procedure preempts any discussion on productivities.

The discussion here is necessarily comparative, and in this sense all four efficiency ratios must be involved. Nevertheless, the emphasis is on the Soviet side of the inequality, and this report excludes extensive comparisons of civilian and military R&D on the American side.

The complete argument develops as follows:

1. A command economy is ill-fitted to accommodate innovation and in this respect is at a disadvantage in relation to a market economy. The discussion of this point is mostly a review of the existing literature molded into the systems approach.

On the foundation of this basic proposition the argument proceeds in two directions: the first is to prove that the actual inputs invested in Soviet MR&D are much larger than is conventionally estimated, and the ratio $(Im/Ic)_{SU}$ is higher than usually assumed.

2. Only a system of priorities that goes much beyond mere resource priority can create conditions necessary for R&D. By definition, a priority can be extended only to a narrow segment of the economy.

3. The priority environment extended to MR&D is very expensive in terms of its effects on other sectors of the economy, especially CR&D. Such costs, by their very nature, are not directly recorded anywhere. Because priorities cannot generally be extended to other sectors besides the military, they impose a heavy burden of opportunity costs on the rest of the economy.

4. Although the military sector enjoys some quasi-natural advantages conducive to R&D, it also suffers from serious shortcomings. Most of the advantages of MR&D are policy-determined and constitute part of the priority system. These advantages, rather than the quasi-natural ones, explain most of the better performance of MR&D. A good part of the debate between the natural advantage and priority schools is on whether to classify the advantages enjoyed by MR&D as natural or as policy-determined.

5. When priority-related costs are added to MR&D budgets, a large part of the efficiency advantages, as calculated by ordinary accounting methods, disappears.

The second line of argument based on point 1 above has two implications for the general statements made as to the relative efficiency of Soviet MR&D.

6. If R&D activity is indeed relatively more expensive in a command than in a market economy, a rational policy will call for relatively less use of it in any economic activity, including the military sector. It follows that different intensities of R&D activities across economic systems could be rational for *both* systems and would not necessarily imply that one side or the other behaves uneconomically or is wasting R&D resources.

7. When R&D inputs in the production of, let us say, defense differ across systems, a measurement of productivity that divides *defense* output by inputs of MR&D is a biased measure of productivity, just as the measure of labor productivity is a biased measure of productivity when the capital-labor ratio varies.

In the ongoing debate of whether greater efficiency or hidden costs explain the apparent Soviet MR&D advantage, I tilt toward the latter. Moreover, I claim that the basic measure giving rise to the paradox is biased in a way that exaggerates its dimensions in the first place.

## II. INNOVATION AND THE COMMAND ECONOMY

This section summarizes the literature on the problems of innovation in a command economy, organized along a system approach. The main source it draws on is Berliner's excellent study (1976). More recent studies that are also relevant are Cocks (1979), Cooper (1979), and Martens and Young (1979).

As a command economy, centrally planned and controlled by a strict bureaucratic hierarchy, the Soviet system has a comparative advantage over a market economy in mission-oriented, simple, routine, large-scale, and well-defined activities. It suffers from a disadvantage in performing activities involving change, uncertainty, flexibility, abstract entities, large variety, small-scale planning, and numerous external connections. Also at a disadvantage in a command economy compared with a market economy are activities whose success depends on strong supervision and control by *clients*, on a good system of prices and costs, on an effective incentive system, and on local, low-level initiative and assumption of responsibility.

One hardly has to elaborate on the high cost per *unit of change* in the Soviet Union. Most plans are changed from one year to the next as far as possible on the basis of "the achieved level"--that is, an equiproportional change of all magnitudes (Birman, 1978). Prices are changed in general once in a decade or more, and it is very difficult to adjust the incentive system in line with other changes. Every planned change creates a chain reaction of necessary adjustments that must be attended to by bureaucrats, committees, etc. Unexpected or unpredictable alterations as well as changes involving uncertainty as to the results are even more difficult to accommodate because planning schedules are taut and reserves lacking. Any divergence from the plan creates very complicated problems of supply and reward. The conservative bias of the bureaucracy is, of course, an additional hurdle to overcome.

The command system is similarly at a disadvantage in handling the production of abstract results that cannot be measured by physicial

units. Because its accounting system is far from perfect, it prefers to define results for purposes of control and rewards in terms of an appropriate physical unit. When this is impossible--because of the nature of the product, or if the product is made jointly--many difficulties arise in defining an effective reward system, and many opportunities for simulation and evasion are opened to managers. The cost per unit of abstract output or of variety is very high.

The unit cost of small-scale operations is higher than that of large-scale ones because of the fixed-cost element per operation or transaction. This is a typical result in a rigid bureaucractic system where every element, operation, or transaction has to go through almost the same stages.

In a tight seller's market, the more an activity depends on the scrutiny and vigilance of clients, the less satisfactory will be the outcome. Put differently, the real cost or price one has to pay in a command environment for a unit of client control is very high because clients' demands often contradict plans, introduce unexpected changes, call for adjustments in the supply patterns, create difficulties in the incentive systems, and so on. Demand power in a seller's market is a big advantage to those who possess it, but it also is very expensive.

In a rigid, hierarchical, centrally directed system, any activity that demands flexibility and initiative from low levels is bound to suffer. Flexibility in organizational patterns creates problems of control from the top, of determination of responsibility for deeds or misdeeds, and complicates planning, supply, and cost accounting. A tight system of control from the top discourages low-level initiative, divergence from set rules, and the assumption of non-assigned responsibilities. It also avoids spreading the accountability of the controlled unit over too-long periods of time. The usual period for planning and control is one year, and any changes whose benefits (or costs) extend beyond that create problems.

Finally, the more the success of a project depends on a sound accounting base--costing and pricing--the slimmer its chances of succeeding in the Soviet environment, because in many respects the

existing cost and price systems reflect neither real social nor private costs.

This profile of attributes and deficiencies of the planning system lists many of the major characteristics and demand of the innovation process in all its stages. Innovation is, in the first place, the production of change. Any innovation introduced into production--even when all the information is availabile--involves new plans and arrangements, new production modes, new materials and supply schedules, new costs and prices to be calculated and approved, and newly defined incentive schedules. In most cases, complete information is lacking, the changes involve high degrees of risk and uncertainty, and the realization period is longer than a single year, the relevant one for bonuses. Moreover, the earlier stages of the production of innovation--basic research, applied research, design and development of prototypes, testing, and experimental series-production--are by nature in a state of permanent change, unpredictability, and uncertainty. As projects develop, so do supply needs, sources, and clients; very little is predictable, from the time it will take to complete a project to the quality of the final result. Very little planning can be done in advance and on time, so that many needs have to be satisfied outside the framework of prior planning.

By nature, the output of all intermediate stages of the innovation process is abstract and cannot be measured except by the final economic results. Because the accounting base is weak, *a priori* assessments of the potential project must be of low quality; the practice of measuring output by the number of projects completed or the number of papers written or designs made is even worse. Similar problems of assessment plague the introduction of new products or processes. The weaknesses of the accounting system and the difficulties in assessing qualitative change are a source of uncertainty, friction with authorities, and abuse. In many cases refusal to grant justified price increases to a given innovation blocks its introduction; but in an increasing number of cases, excessive price hikes are granted to simulated or spurious innovations and improvements. Insistence on a one-year accounting and reward period makes things even more difficult. There is very little correspondence

between the criteria that determine rewards and sanctions in R&D institutions and in production enterprises that introduce them, and the real economic effect or outcome of the innovation. There is wide room for simulating good results and obtaining high rewards with unsatisfactory real results.

R&D institutions, which typically work for results extending beyond the current year, find themselves cut off from resources--even below planned levels--that were shifted to assure fulfillment of current production plans. R&D institutions are the major small-scale producers in the economy. The burden they impose on the supply network must be several times the value of the goods they require. The natural reaction of the supply network is to try to avoid these chores, creating even larger supply difficulties and stimulating even more expensive efforts to avoid supply problems by self production.

It is hard to exaggerate the negative effects of the inability or reluctance of the system to allow greater initiative at low levels and encourage more organizational flexibility, both so essential to productive innovation.

To all these factors one has to add the seller's market environment, which makes innovation less efficient and more expensive in at least two ways. On the one hand it discourages innovation and improvement because buyers can easily be forced to buy old equipment and materials. An authority that would like to encourage innovation would have to pay dearly to overcome this tendency. On the other hand a nondiscriminating buyer will more easily absorb inefficient and expensive innovations offered by a seller who found a way to receive material rewards for them or by the authorities who encourage "innovations." The buyer may even be interested in buying them, efficient or not, if he is rewarded for the rate of innovation or if he can easily shift any extra costs to the subsequent buyer or financer of the project. These two negative effects of the seller's market atmosphere also underline the damaging consequences of the use of the incentive system to overcome many of the other objective hindrances to innovation. In a seller's market any increase in the level of incentives to innovation, or liberalization in price formation for new goods, immediately creates

a large volume of spurious, artificial innovations and excessive price increases that buyers cannot refuse to absorb. Even worse, they will accept the increases and pass them on to the next buyer (see below).

When these problems are compared with the routine large-scale production of an established product of uniform quality, with long-established supply lines and waiting clients, with fixed prices for the last ten years and annual plans that are "x percent above the previously achieved level" it might be possible to appreciate the problems of innovations in a controlled economy.

Until now the argument has used the term cost in its general sense: that a unit of innovation demands more real resources in a controlled economy than in a market economy. In this respect the conclusion applies to the social costs as they should be perceived by the system directors. However, most of the elements of extra real costs discussed above are not charged directly in the regular costing practices of the service granted nor of the units to which they are supplied. Rather, they reflect the inability of the system to accommodate demands of innovating units and the resulting extra costs they or other units incurred. As a rule there is no direct charge for late supply, small orders, delays in decisions on prices, faulty design, bottlenecks in the planning process, etc. These show up in the *costs* or inefficiency of the innovation, not as direct inputs into the process.

When an R&D institute tries to overcome some of these difficulties, it incurs actual costs (on self-production of what had to be supplied, for example) but these costs do not necessarily appear in the official plan. The same is true when an R&D institute finds ways to secure what it needs, uses clout and "blat" (connivance) to make the necessary changes in plans, etc. In such a case the cost of disrupting planned routines will be paid by the enterprises that suffer from the disruptions. One result is that *a priori* calculation of expected costs and the economic effectiveness of proposed innovations are bound to be overoptimistic for the party involved as well as for society.[3] This is a permanent source of friction between the seller and client of

[3] Other faults in the costing and accounting principles and practices further widen this overoptimistic bias.

innovations in the Soviet Union at every stage. A second result is that even the system directors may to some extent overestimate the net benefits of innovations (see below). Furthermore, the private costs of innovation, as viewed by the managers of the innovation introducing unit, are bound to be higher than the social costs. There are a number of reasons for this: First, superiors usually expect an innovator to perform better--according to the ex-ante economic-effectiveness calculation--than he really can. It follows that his reward would be lower than intended. Second, an innovator calculates on the basis of the short run and thus completely discounts longer range benefits. Third, the many loopholes in the incentives for innovation make it much more attractive to the individual manager to engage in false (or simulated) than in real innovation. It may be easier to get a false innovation approved than really to introduce one. Finally, the introduction of an innovation may have some external effects that the enterprise manager cannot cope with.

The cumulative effect of all these factors on the innovation process in the Soviet Union is that decisionmakers at every stage, when faced with a choice, will prefer to direct resources to production rather than innovation; and when forced to innovate, they will use at least to some degree the many loopholes available to simulate. Together with objective difficulties and the weaknesses of the accounting system, the deviations between the intended or planned amount and quality of innovation and its realization will widen as the process goes through its various stages. One obvious result is that less innovation will be generated. A second is that there will be a growing conflict of interest between sellers and potential users as one proceeds from early to final stages of the introduction of innovations.

In addition to the problems that every innovator has to face in his own institute or enterprise, he also has to buy an innovative input (idea, design, prototype, new machine) from the previous stage that is already overpriced or of lower quality than it should be, or both. Some Soviet as well as Western students attribute much of this price and quality gap between sellers and buyers of innovations to a technological bias of the R&D sector--that is, the tendency to develop

technologies that are "too advanced" for the use they are put to and thus economically inefficient.

Two sources of technological bias are referred to in the West: the engineer's bias toward developing the perfect product, in many cases beyond the optimal level of development from an economic point of view, and efforts by companies to increase the volume of government contracts when they are made on the basis of cost plus. In both cases more R&D output (sometimes unnecessary) is produced and sold. Both motives probably exist in the Soviet Union to some extent, but in the circumstances described above, excessive *technology* is unlikely to be a major factor explaining the gap. In the Soviet Union a third type of bias--goldplating--has been developed.[4] The main motive given for goldplating on the part of R&D producers is to maximize their gross sales figures *per unit of value added* (or minimize the latter for a given sales target). In this way they can fulfill plans and collect bonuses (paid on the basic sales figures) without stretching their own production capacity too much. This can be achieved by using expensive inputs and producing large units. So if a given innovation can be mounted on either a large scale or a small scale machine, the former will be chosen. It is unlikely that the *innovative element* of the new machine will be excessive because it goes against the idea of goldplating, which is to crowd the new product with every possible input *except* value added. In most cases goldplating will be in the form of machines that are too heavy or too big or made of unnecessarily expensive materials; only in a minority of cases will there be excessive new R&D output content.[5]

To summarize: in a seller's market for products there is no demand for innovation, especially for non-productive innovation. The market for innovations may be the only market in the Soviet Union in which excess supply prevails. Still this does not create pressure to improve

[4] See Berliner, 1976, pp. 352-360 and the references there.

[5] This comes especially as a response to Nancy Nimitz' claim that "goldplating" means a lot of R&D in the wrong direction (Nimitz, 1978). See a supporting statement in Berliner, 1976, pp. 249, 375-380.

the product because sales of innovations have not yet been made a criterion of success, nor is it so easy to turn them into one.[6]

What are the policy implications of all the above and what are the actual Soviet policies and options with respect to R&D? The question of how much innovation to use in the production process is first posed in a static situation in which a given output of any kind, Y, can be produced by two inputs--routine (R) and innovation (N) (Fig. 1). The innovation *input* is the *output* of the R&D sector, and the routine input has no R&D component. If the optimal position for a market economy is point $M_0$ then the optimal position for the Soviet Union is somewhere to the right--point C, because the relative price of N to R is higher in the Soviet Union than in a market economy. Even if we assume that the system directors in the Soviet Union aim at $C_0$, the actual level of innovation taking place is at $C_p$, reflecting the still higher relative price of N perceived by individual managers.[7]

The figure can also be used in a semi-dynamic context when $Y_0$ is replaced by $\Delta Y_0$, a given increment to the output level. The choice presented is between growth strategies that are more or less N intensive. In such a context the relative price of R to N includes the choice of the path on which one can move faster.

The available evidence supports a number of aspects of the positioning of the three points in Fig. 1: that the amount of innovation, or N, for a given level of output is lower in the Soviet Union than in leading market economies (point $M_0$ to the left of points $C_0$ and $C_p$); that to some extent the Soviet government has intentially followed a route of growth that relies less on innovation--extensive vs. intensive growth model, emphasis on quantity rather than on quality--and that the system directors have been unhappy with the achievements on the innovation front ($C_p$ to the right of $C_0$) and look for ways to improve them.

In the past the relative price of R may also have been lower in the Soviet Union because abundant reserves of regular inputs could be

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[6] I thank Joseph Berliner for suggesting his formulation to me.

[7] If, as claimed, the system directors are overoptimistic or have a technological bias, they may aim at a point to the left of $C_0$. Even in such a case $C_p$ will be to the right of $C_0$.

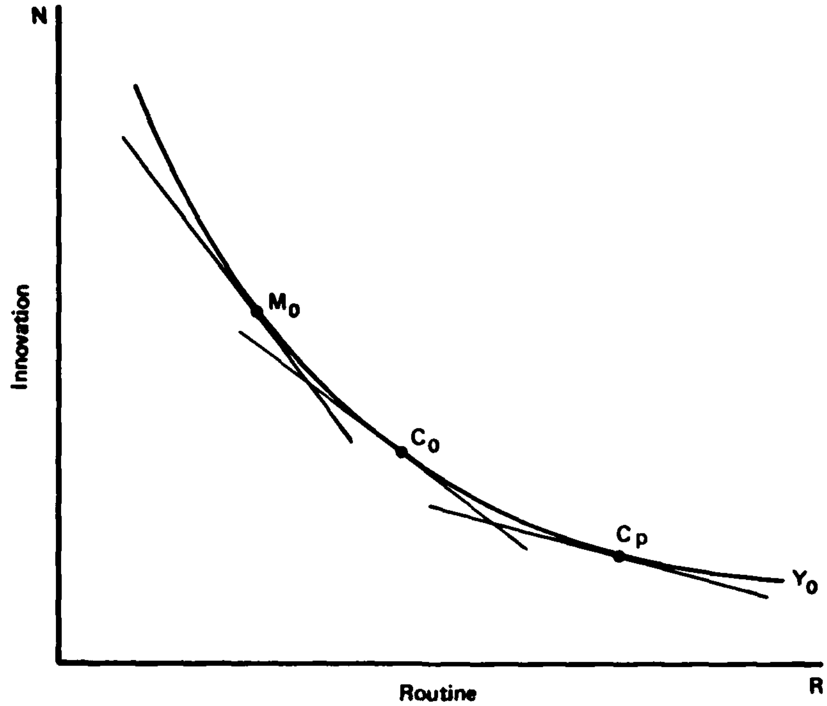


Fig. 1—Production isoquant with routine and innovation inputs, market and command economy

drawn into production. For this reason $C_0$ may have been even further to the right, but the depletion of those reserves over time has pushed it to the left. Some of the increased attention to the question of innovation in the Soviet Union in the last 15 years or so may have to do with this movement.

But even when these reserves are brought to normal levels, the choice of the form of resources designated for growth purposes is still there, whether to be used for R&D or for larger investments in old technologies. The claim is still valid that if N is more expensive, more R ought to be used. A more ambitious growth target requires, of course, more inputs of *all kinds*, R as well as N.

Some of the recent pressures from the top to raise the level of N production may be directed to shifting the isoquant of a given output inward rather than to changing the proportion between R and N. In

addition to accepting a lower level of innovation, the system directors made a considerable effort to close the gap between the optimum level of innovation and that reached by the system (the $C_0 - C_p$ gap), and to try to alleviate some of the system's impediments to innovation, thus allowing the optimum C to move in the direction of $M_0$. Although some such improvements have been made (see Cooper, 1979), many reforms in this direction are hindered by the opportunities they provide for more and costly abuses side by side with genuine innovations. I have already mentioned the abuses associated with the general increase, over the last 15 years, of the direct incentives for innovations. Likewise, the steps taken to encourage a more economical use of capital and by implication a higher rate of innovation--the imposition of interest payments and minimum rates of return on investments--often resulted in fewer rather than more innovations (Schroeder, 1970, p. 29; Berliner, 1976, p. 107; and Nimitz, 1978).

To avert many complaints about refusals to secure high enough prices for new products and about delays in decisions on new prices, the authorities somewhat liberalized the process of price determination of new products. The result is an avalanche of complaints concerning spurious price increases (there are some estimates that put the annual rate of price increase in the machinery industry at 4 percent or more in the last 15 years) far beyond the value of the embodied innovation, whether genuine or simulated.

Another important organizational change relevant to R&D has been the institution of the technical-production associations, or even the general associations. In contrast with the past, R&D will be closer and more organically connected to actual production and to its needs. Although the previous separation of R&D from production had its obvious weaknesses, their unification under one roof raises the problem that R&D resources may be used for routine production. This has happened in the past to a large extent and is happening again under this new form of organization. Finally, to avoid goldplating of all kinds, one school in the Soviet Union advocates changing the main success criterion from total sales to net output. The caution with which a limited experiment in this direction has been proceeding points to the lack of illusions as to its outcome.

The wave of new reforms in organization, accounting, and incentives demonstrates that the weaknesses of the old arrangements have been recognized and that there is room for improvement even under the present system. Some students, notably Cooper (1979) and Spechler (1979) believe that these reforms have produced significant results in the sphere of innovation, but even they agree that all these reforms encounter difficulties of implementation and open Pandora's boxes of new problems that diminish their net positive results. Certainly there are ways to improve upon the present situation; however, improvements are difficult and expensive and their end results moderate.

Another route of action is to follow the principle of comparative advantage and to exchange R goods for N goods in the world market--that is, to import technology in all forms. Like every other "follower" country, the Soviet Union has borrowed technology from the West all along, mostly in the form of reverse engineering of individual pieces of equipment purchased or obtained in the West. During recent years more "liquid" forms of transfer have been emphasized through trade and technical agreements. A debate is going on in the West and in the Soviet Union as to how beneficial this exchange has been, and both sides now seem to be somewhat disillusioned after having high expectations in the near past. It should have been clear from the outset that nothing can replace the development of endogenous R&D capability. Further, technological shots in the arm cannot change the basic shortcomings that prevent a command economy from developing satisfactory endogenous capability. Such a transfer of technology can, however, provide a constant stream of tested and proven technologies with set standards of quality and performance to key sectors of the Soviet economy, thus jumping over a number of R&D stages and numerous bureaucratic hurdles. It avoids much of the added goldplating of local innovations. It also has a potential of faster diffusion, although like all innovations it will suffer from difficulties in supply, conservatism, etc.

Indeed, in recent years the import of new machinery from the West is significant compared with the introduction of new endogenously developed machines: Of all the machinery produced in the Soviet Union in

1973, 3.5 percent were brand new, 13.2 percent were up to three years in production,[8] and between 1.5 and 3 percent were imported from the West.[9] Even if we allow for the fact that some of those machines are imported repeatedly during more than one year, the proportion of imports may have reached a third or more of all technically new machines installed. In view of this, there is no question that a massive effort is being undertaken to supplement endogenous innovation by trade.

A third set of policies that has been used to encourage some R&D activities is called priority treatment. That system and its significance for R&D are examined in the next section.

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[8]Nimitz, 1978. This figure includes machines that are new only in their date of manufacture, not in their technical level.

[9]Hanson, 1976, p. 796. These are typical figures for the late 1960s and early 1970s. The lower figure is arrived at on the basis of official exchange rates and the higher on the basis of a rate twice as favorable to the dollar.

## III. ALLOCATION BY PRIORITIES IN A COMMAND ECONOMY[10]

In a pure market economy, high priority "needs" show up in markets as the highest bidders, who obtain what they need ahead of everybody else. Only in cases of market failure can priority treatment be in order. In a centrally planned economy, priority considerations enter at three levels: first as directives to planners, telling them how to prepare plans; second as directives to the executors of plans telling them how to behave when plans are not completely fulfilled; and third as grants of permission to break restrictive, organizational, and operational rules and to follow a specific set of preferential rules that facilitate and expedite operations. At any of these levels priority treatment is needed, or is operative, only if it relocates something for which there is excess demand under regular conditions. By definition priority can be awarded only to a small segment of the economy. As a rule no price is charged for priority treatment (if there were a high enough price no priority would have been needed) and the cost is thus borne directly or indirectly by the non-priority sectors. Finally, the priority treatment is a set of voluntary policies that can be endowed to different sectors, shifted among sectors, or abolished altogether. In this respect the accrued benefits from priority treatment to the preferred sector are the opportunity costs to the rest of the economy.

The level of demand or room for priority treatment in any given situation depends on the level of allocative efficiency of other, more routine allocative agents. If prices could be made to reflect scarcities and the incentive system could be reformed to reflect these prices more accurately, there would be less excess demand and less need for rationing according to priorities. Prices, however, are not intended to perform a major allocative function in the Soviet Union, but planning is.

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[10] This section draws upon the discussion on priorities to MR&D included in Alexander, 1976, 1978a, and especially 1978b; Holloway, 1976, 1977; Agursky and Adomeit, 1977; Berliner, 1976, pp. 504-510; as well as Ofer, 1975.

Were the planning system more efficient and less tight, most of the priorities could be incorporated in the plan and fewer second and third level priorities, which are more expensive (because they are more disruptive), would be needed. The combination of the small allocative function performed by prices and imperfect and tight planning systems has created ample demand and need for priority treatment in the Soviet Union since the beginning of planning.

The level of demand or need for priority treatment varies also between sectors of the economy or types of economic activity. As indicated in the previous section, there are sectors or activities whose mode of operation fits the existing system worse than others. One example is agriculture, which is much less fit for strict central control than manufacturing. The results of denying priority to agriculture were so devastating that the system directors had to allow private production within Soviet agriculture, a concession that only partially corrected the consequences of the gap between the needs of the sector and those of the system. There are similar systematic problems in the construction industry and in services. The R&D sector is possibly the least adaptable to a command economy. Its needs are most difficult to provide, and its preferred mode of operation is diametrically opposed to that followed by the system. Only a massive and well-directed priority program at all the levels mentioned above, but especially the second and third, can create conditions for efficient operation of innovation activity, and this only within a limited range of the R&D frontier.

Such priority treatment has been given to MR&D and necessarily denied most sectors of CR&D. The following is a list of the main aspects of the priority treatment awarded to MR&D in the Soviet Union. Although no direct quantitative measure of them is possible, the above analysis should provide enough support to the claim that they are highly significant. A second purpose of this listing is to show that priority treatment on the input or supply side is very important, but other aspects--in the modes of production and on the demand side--are just as important, perhaps more so.

First, the military sector, and MR&D as part of it, enjoys preferential treatment in the allocation of all inputs--labor, capital, and materials. It is assured of higher quality inputs of all types, and a special and costly effort is made to supply them in the planned or needed qualities and on time. Most of the benefits thus provided are only partly paid for from budgets of the military sector (MS), because capital, new products and materials, and high quality--all of which the military and MR&D receive in abnormal proportions--are all underpriced in the Soviet Union. That new products are underpriced is demonstrated by the fact that many of them are allocated exclusively to the MS. Despite some recent developments, quality is still grossly underpriced in the Soviet Union (Berliner, 1976, pp. 248-249). MR&D needs and gets top quality in all inputs and reaps a significant economic windfall.

Everybody seems to agree on this point with respect to material inputs, but a number of emigrants who were engaged in R&D activities in the Soviet Union question whether the MS indeed continues to get the best scientific and engineering manpower (Agursky and Adomeit, 1977, pp. 29-41; and Perakh, 1976, p. 181). Their argument is that the strict discipline and the limitations imposed by secrecy discourage the best men from working in strictly military R&D organizations. This point is apparently at least partly valid. Such situations are handled by the military by extensively enlisting civilian scientific and R&D institutions to work on military projects (Kassel, 1974; Agursky and Adomeit, 1977, p. 7; Perakh, 1976, pp. 191-192; and Alexander, 1978b, p. 21). Some of these arrangements are permanent (with many institutes of the Academy of Sciences) and some are on an ad-hoc basis. The upshot is the same: The MS gets the best people to work for its needs and, by and large, in the wage field as in others, the best quality is underpriced (Ofer, 1975, pp. 8-13).

Possibly no lesser benefits for MR&D are derived from the fact that planned and non-planned supplies are provided to it on time. Up to this day the number one complaint of managers is the uncertainty and unpredictability of material supply. Supplying R&D is a very costly operation. Doing it on time in a tight environment is extremely costly

to those whose supply schedules have to be disrupted: Very little if anything is paid extra for prompt supply.

The coordination of supply as well as all other aspects of military R&D and production is put in the control of a number of bodies that are completely absent in the civilian sector. The two most important are the Defense Council (an advisory board to the Politbureau) and the Military Industrial Commission (an executive body under the Council of Ministers) both of which are manned by people at the top hierarchy of the Party, the military, and the government (Alexander, 1978b, pp. 14-16, 20-21, 27). These bodies have the power to see to it that plans in their fields are fulfilled. They can make quick decisions when needed, reallocate resources from civilian to military and within the military sector, directly control and assign responsibilities, intervene whenever necessary to change the organizational structure or project assignments, cut through red tape, eliminate cost bottlenecks, etc. All such actions are very costly because they require the attention of the top echelons of the leadership, deny other sectors similar treatment, and disrupt the tenuous balance in the other sectors through ad hoc decisions.

Direct control of at least the major projects in the military sector can significantly improve the discipline of and incentives to the people engaged in those projects compared with the impersonal system applied to everybody else. It also allows for much more organizational flexibility and initiative at the level of operations because responsibility can be demanded and assigned on the basis of personal knowledge. Here too the price to the other sectors that are supervised mechanically is very high. This autonomy and flexibility are best seen in the special status and power of the chief designer of major MR&D programs (Alexander, 1976, p. 5).

The military production sector is integrated verically to a much higher degree than most civilian industries. This gives it a very important advantage in supply production and R&D activities (Alexander, 1978b, pp. 21-23). In many cases, the civilian sector cannot be so integrated because potential elements are already integrated into the military sector, or because central planners withhold approval to keep their own control over this resource base.

Many of the advantages granted to the MR&D sector in the sphere of inputs and production are reinforced because the military sector acts as a powerful client in an otherwise general seller's market environment. Clients of most goods produced for civilian users complain about poor quality, but in most cases they have to take the goods anyhow for lack of an alternative. But military clients can refuse to buy what *they* consider less than acceptable quality without incurring an additional expense; it is up to the producer to provide the right quality the next time around. Special military representatives of the specific military clients perform the quality control at the producing units. Information about their authority is not uniform but they clearly have rejection rights. According to some accounts, they are also allowed to intervene in matters of prices and costs--demand explanations and impose their views (Alexander, 1978b, p. 19; and Agursky and Adomeit, 1977, pp. 16-17). In most cases the demanded quality level is the one prescribed in the plan, but there is also no additional compensation to the producing unit for meticulous control. Producers for the military simply cannot get away with what civilian producers can. And, indeed, there are accounts of reluctance of producers and R&D institutions to work for the military. Other accounts, however, claim that at least in some cases, civilian R&D institutes are interested in military contracts, which provide them with funds to finance equipment, overhead, and work on civilian projects. Some of the accounts also claim that sometimes work on the military project does not have to be taken very seriously and "negative" results can be reported after a while.[11] Although such reports underscore the fact that the military sector suffers from pretty much the same problems as the civilian sector--a very important reminder--it also implies that at least in some cases the military uses not only a longer stick to enforce its demands but also a juicier carrot. This carrot, of course, is an expense that should appear in some budget. The combination of stick and carrot that only the military can use produces results much

[11] Reported by Alexander, 1977.

beyond those the civilian sector can hope to obtain with its lack of funds and clout.

But even before controlling product quality, the military client has much more to say than his civilian counterpart in determining the types of innovations to be introduced and their specific characteristics. There is some debate in the western literature on the exact division of power among the client, the supplier of funds, and the designers of new weapon systems. The institutional arrangements described above create a situation in which each of these three parties takes into consideration the problems and constraints of the other two in the process of shaping its own views (Alexander, 1978b, Ch. III and p. 27; Wolfe, 1977, pp. 30-35).

Finally, it takes a demanding client to activate and use many of the aspects of preferential treatment in the supply and production spheres. Such a client will be on the average less submissive to problems and difficulties, less inclined to shift them forward, and more insistent on his rights.

The advantages enjoyed by the military on the demand side are claimed by some (notably Nimitz, 1971, p. 43; 1974, pp. 43, 45; 1978) to follow in part from the natural position of the military as a single buyer. The main discussion on the source of advantages enjoyed by the military is discussed in the next section. I shall merely state here that in the Soviet environment buyer power does not depend on the number of buyers of a certain good or on their will; buyer power has to be granted and backed by the leadership and it can be given to anybody. The presence of quality controllers on behalf of the client in the producer's shop cannot be based on a client's will; if it were possible many would choose to have it. The same is true with respect to the choice of projects or to the formation of a top notch coordinating body to cut through red tape and increase control. These methods are not military secrets. They are all plain devices awarded to the military to permit smoother MR&D and production activities and deny them to everybody else.

The effect of all the elements of priority treatment is larger than the sum of the individual effects of each element. Likewise,

their denial creates cumulative negative effects stronger than that caused by each one separately. The availability of more resources and facilities and better inputs creates the favorable environment in which stricter demands can be more easily and more efficiently met; all these raise the motivation level and create a greater sense of responsibility, commitment and initiative. Lack of adequate facilities and resources on one side and a weak client chain on the other create frustrations and open opportunities for low quality work, which further reduces the client's interest in innovation, and so on in a vicious circle.

## IV. THE SOURCES OF HIGHER RELATIVE EFFICIENCY OF THE MILITARY SECTOR IN A COMMAND ECONOMY

Every economic system has some special characteristics of military R&D and production that distinguish them from regular economic activity. Some of these special characteristics are uniform across systems and some are conditional on the system. In some other cases the different character of civilian production across systems is responsible for the differences between the civilian and military sectors among systems. My interest is in differences in the relative efficiency of military and civilian R&D across systems, so all these types of differences matter.

For both superpowers MR&D means scientific and innovative activities at the limits of knowledge and engineering: The development of new weapons systems requires new scientific discoveries in various fields of physics, development of new materials, new advances in electronics, etc. In this respect MR&D is more demanding and costly than most CR&D, although civilian R&D in leading sectors may encounter similar problems. Competition from the other superpower creates additional pressures on the military sector to obtain quick results, and this demand for speed further raises the costs of new developments. All this is true for both systems but here the differences begin, and most of them tilt the balance of relative efficiency against the Soviet Union. First, as seen above, the unit of cost of R&D is higher in the Soviet Union; it is even higher for activities at the outer limits of existing knowledge. Similarly, the development and production of weapons involves a very high proportion of series production and production to order (space vehicles, aircraft, shipbuilding, to mention a few) in which the Soviet system is again at a disadvantage relative to mass production.

Second, being behind the United States in general technological level, MR&D in the Soviet Union can rely much less on innovative and scientific activities in the civilian sector. To keep up with the United States, the level of achievement of MR&D must be way above that

of its civilian counterpart, which means that it has to develop, or to forgo, many items that are available to the American MR&D sector. Third, as a follower in terms of technology in the world, the Soviet Union can borrow or import civilian technology from the West with ease. It is more difficult to borrow military technology, which is kept under a cover of secrecy, and such borrowing is less helpful because in military development the Soviet Union cannot afford to be a total follower.[12] Although in the military sphere the Soviet Union must keep up with the competition, with much less harm it can allow itself to remain behind the upper limits of world technological advance in the civilian sector, thus further significantly reducing the relative cost of innovations there. So the arms race imposes competition on the Soviet Union in the sphere of MR&D, where it suffers from an initial systematic disadvantage.

Some analysts see in this foreign competition an asset or source of strength rather than a liability to Soviet MR&D as claimed here. Although lack of internal competition is one of the major reasons for inefficiency in the economy, so the argument goes, the one sector that does face competition is forced to live up to its demands (Nimitz, 1974, pp. 44-45; Berliner, 1976, p. 508). The military sector really needs the output of the R&D supplier because of competition from the United States, and the civilian sector in many cases tries to avoid R&D, an important difference between the two. This is an objective factor that dictates the high level of MR&D *output*. For many new weapon systems it dictates high minimum quality standards and stiff performance requirements. The question is, How much of this competitive pressure is directed toward higher efficiency in MR&D activity and how much toward more inputs and priorities?

From the point of view of Soviet military demand, the U.S. competition is not mainly about levels of efficiency in the *development* of new weapons (as distinguished from the weapons themselves) but about the end result, not about their cost or price but about their

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[12] The Soviet Union can quite easily borrow knowledge on basic concepts of newly developed weapon systems, and this is no doubt an important advantage.

performance or output level. When economists talk about the driving force of competition they mean cost or price competition. The question is, Can you produce an equivalent good at the same price as your competition or a lower one? The Soviet Union does not really compete to sell weapons in the world market (in most cases where such competition occurs, the Soviet Union loses). The competition is rather on total military capability and performance, not on cost. The cost of the military effort is, of course, on the minds of the system directors, and they should be looking for ways to reduce the defense burden, especially because they have the disadvantage of working with a GNP just above half that of the United States. The optimal way to minimize the burden, given the level of defense output, is to improve the level of efficiency of *all* resources available to the economy and maximize the rate of growth of the economy. That is, the burden can be reduced by decreasing defense costs for a given GNP or by increasing GNP for the same defense cost. Efforts must be made to minimize costs of military production, but an unbalanced effort in this direction will be suboptimal if similar efforts in other directions can be more effective. Given the specific difficulties in MR&D, it may well be better to direct efforts to increase efficiency and spur growth in some other sectors of the economy.[13]

Part of the competitive pressure should be directed toward higher efficiency in MR&D. The mere interest of the military in the outcome of the R&D effort certainly creates better working relations and more cooperation. There may be complementarity between demands for high technological standards and efficiency. Finally, despite the above claims for spreading the pressures of outside competition over the entire economy, part of the pressure may be confined to a limited military budget. The degree to which Soviet defense budgets are tight is controversial.

Finally, this external competition imposes additional burdens on the economy in an area (R&D) where the Soviet Union finds it most

[13]To illustrate, if with a given amount of effort 2 billion rubles can be saved by improving tractor production or 1 billion by increasing the efficiency of tank production, the former action should be preferred.

difficult to respond, and the costly priority treatment may be the only way possible to meet this outside challenge.

National security is very high on the list of values of most societies, and to serve that cause by activities in the military sector enjoys a certain amount of extra status or prestige. The motivational and incentive effect of this factor may be stronger in the Soviet Union than in the United States on a number of counts. First, in a system where material incentives are not that effective, motivation based on nonmaterial elements may be more important. Second, the fear of war, which still reflects the experience of World War II, and the feeling of national pride based on the Soviet military might increase the significance of this factor (Wolfe, 1977, pp. 38-40). Finally, these sentiments are used by official propaganda to enhance national feelings and identification with the armed forces; as a by-product this can be part of the priority treatment, a convenient way to increase pressures from the top on all the parties involved. In evaluating the national security argument, however, one should take into account that motivation based on emergency situations wears off after a while and becomes more and more difficult to sustain in the long run.

The relative efficiency of military activities may also be affected by the secrecy that covers such activities in all countries. Because the secrecy is heavier in the Soviet Union, its effects for better or worse are more pronounced there than in the United States. The main goal of secrecy is, of course, to deny information to military adversaries, and there is no question that the Soviet Union has the upper hand at both ends of the rope--it can take greater advantage of U.S. secrets than the United States can of Soviet ones. This may grant Soviet MR&D a productivity advantage over its U.S. counterpart.[14]

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[14] Secrecy can also be used (and has been used) for purposes of bluffing--that is, make your adversary believe you have more and better equipment than you actually possess. Estimates of Soviet MR&D efficiency that are based on such inflated output figures will of course exaggerate its level. This has happened in the past (MiG-25) and may happen again (Ofer, 1975, pp. 36-37).

Added benefits from secrecy on the Soviet side result from denying the civilian sector the use of military innovations, thus easing the competition for their scarce supply.

Against these advantages one should weigh some negative effects of secrecy that are more pronounced under Soviet conditions. Secrecy is claimed to be very harmful to the efficiency of Soviet MR&D in that it impedes the flow of information within the sector, helps to cover up pockets of ineptitude, is used as an excuse for failures of all kinds, and drives away good people. All this is documented in detail by Agursky and Adomeit (1977, pp. 19-28), among others.

Another major characteristic of the military sector anywhere is that it deals with a public good. It has one client--the government--which also determines the demand and has different degrees of control over production and costs. In the United States part of MR&D and almost all production for the military is performed by the private sector. In the Soviet Union, where the entire production is owned by the government, negotiations are performed between the administrative departments, institutes and enterprises on an accounting (khozraschet) basis.

With few exceptions, bureaucratic systems operate less efficiently than market systems, particularly in R&D, where changes, flexibility, and initiative are needed. These are anathema to the conservatively minded bureaucratic stereotype who shies away from responsibility and is frightened by the prospect of taking the initiative. If this is so, then MR&D commands a relative advantage in the Soviet Union where the *entire* system is under the bureaucratic yoke, whereas in the United States the rest of the economy prospers in a market environment. Furthermore, because private enterprise is profit motivated--while the typical public official is less driven to protect the public interest--private developers of weapons in the United States can take advantage of their client, the government, by overcharging it and by pushing it into expensive projects that otherwise might not be undertaken. This cannot happen between two units in the private market. There is no such asymmetry in the Soviet Union between the military and the civilian sector--they have bureaucrats on both sides (Nimitz, 1978, pp. 30-32;

Alexander, 1976). The developers of MR&D in a market economy are private enterprises with market orientation and mode of operation and, although the client may be less strict, there is ample competition for contracts on the demand side. These two features do not exist in the Soviet Union, of course.

According to some opinions, some of the most noted deficiencies associated with bureaucrats--conservatism, lack of initiative, timidity, aversion to (big) changes--may be in fact virtues in running the Soviet MR&D programs. Such programs are said to emphasize evolutionary, gradual changes, to maximize the use of off-the-shelf parts and components and subsystems of older models, to avoid complicated automatic devices and expensive human-engineering elements, etc. (Alexander, 1976, 1978a, 1978b; Nimitz, 1974; Holloway, 1976; Perry, 1973). All this in contrast to the American start-from-scratch, over-engineered, gadget-oriented approach.

While praising the American way, Alexander states, "The pattern of simplicity, commonality and incremental change may be in part a successful response to the limitations and constraints of the centrally planned, seller-dominated Soviet economy."[15] A constrained optimum is seldom equal to an unconstrained one. It may sometimes happen that one bad--bureaucratic conservatism--prevents another bad--technological bias in weapon development--from materializing. My feeling is that the characteristics of Soviet weapon developments have other explanations, that they are not net advantages and that the conservative nature of the Soviet bureaucracy impedes rather than helps its MR&D program.

A second major property of military production resulting from its being a public good is that the decisionmaking process concerning development and acquisition cannot be based on profit maximization as in the case of regular private goods. In almost all cases, the evaluation of a new weapon's worthiness or a decision on its specific attributes is made on the basis of cost effectiveness, which involves a first stage of weighting the technical contributions to military

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[15] Alexander, 1976, p. v. This assessment is even stronger in Alexander, 1978a, pp. 102-127, and 1978b, pp. 14-17.

capabilities against the estimated costs of production, or comparing two or more alternatives along these criteria. Although cost considerations come in at this stage of major decisions, outside challenges, time schedules, needs, and so on also play a major role.

Once the technical requirements of a new weapon system are decided upon, all that remains is to minimize development and production costs. Such a cost effectiveness decision process is less efficient than profit maximizing under ideal market conditions; the absence of a market test also makes it very difficult to determine whether a previous decision was optimal. In the Soviet Union, however, such a two-stage decision process may be more effective than the Soviet version of profit maximizing calculations involved in the decisions on new products in the civilian sector. The weaknesses of the price system and the distortions created by the nonfocused system discussed above, together with the administrative entanglements involved, make the civilian decisionmaking process unreliable and in many cases an impediment to innovation. When prices are too high for developers on the civilian side the innovations are not made, whether they should be or not. I believe that under the existing accounting rules many more mistakes are made in the field of innovations in the civilian sector under rules of economic effectiveness than in the military sector under cost effectiveness. If so, why not use military procedures in the civilian sector?

These arguments hold for the development of new weapons systems only, not for the development of the equipment and machinery necessary for their production. In this last sphere, the same criteria apply to both sectors. All indications here are that the military sector in the Soviet Union introduces processes and innovations that would be considered unprofitable in the civilian sector. Most complaints in the civilian sector about new machinery are that it is too expensive because, among other factors, it is too capital-intensive (Rumiantsev, 1971, p. 9; *Pravda*, August 20, 1971, p. 2). Because the military sector is characterized by a highly capital-intensive production system, the use of technically superior but economically unprofitable processes is not completely absent there either.

As a client of a public good, the military is also a sole buyer of most weapon systems; thereby it commands monopsonistic power over suppliers who can be played one against the other. Indeed, being a sole buyer is a source of monopsonistic power under market conditions, in the United States for example. In a centrally planned system, however, this is neither a sufficient nor necessary condition for holding such power. On the one hand, the organization of production and supply puts almost every branch or sector of the economy in the potential position of sole buyer, but on the other hand such a position, per se, does not generate market power. Such power has to be explicitly granted by the authorities and it can be awarded to any sector. Under the Soviet system, the purchasing department of a ministry or a major *glavk* is a potential monopsony. Although it is true that there are many clients for tractors or refrigerators in the Soviet Union, but only one final client for tanks, the purchasing departments for the Ministry of Agriculture or that of the Ministry of Wholesale Trade can represent all such clients if granted the power. If it receives absolute power to reject inferior quality equipment, the Department of Wholesale Trade, which buys and distributes all refrigerators, can force refrigerator producers to improve their product and make substantial use of the relevant R&D discoveries, etc. Likewise, the monopsonistic power of a true sole buyer is worth very little without government support.

Also in this connection remember that the military is the sole buyer only of final products. When it comes to inputs and materials, it lacks that advantage unless priority arrangements and vertical integration provide it with more influence on suppliers than other clients.

In a recent work Nimitz discussed two extreme hypotheses about the source of efficiency of MR&D, the "technology push plus planners' priorities" *vs.* the "demand pull versus seller's market" models (1978). She concludes that the former is "implausible" and the latter must dominate. The flaw in this argument is that most of the sources of strength that create the demand pull are *granted* as crucial parts of the priority system and are not *natural* advantages. The distinction between the two models collapses and the priorities dominate as the major factor. The remaining more or less natural advantages of the

military sector have to be weighted against a number of rather significant disadvantages. The balance is not clear and in any event the net advantage cannot be significant.

## V. THE SOURCES OF A LOWER INNOVATION INTENSITY IN MR&D AND ITS IMPLICATIONS[16]

On the basis of the foregoing discussion we can turn back to the overall question of relative Soviet efficiency in MR&D activity. The exposition is carried out with the help of a production model that includes military and civilian sectors.

Let PP in Fig. 2(a) be an American production possibility curve between innovation (N) and routine production (R), two intermediate *inputs* produced from the primary resources of the economy. The inputs N and R are then used to produce two exclusive services: defense (D) and civilian services (C). The curves $d_0$ and $C_0$ are representative isoquants of the production functions for defense and civilian services, but they are drawn from opposite origins as in the usual contract-curve analysis. Assume that the amount of defense is predetermined--at $d_0$--by external considerations. It is assumed that there is a minimum requirement of N in the production of defense indicated by the vector $(N/R)_{min}$. This reflects the demands of modern warfare. In equilibrium C is determined on PP simultaneously with point $E_{US}$ on the contract curve between D and C. The optimal conditions are that at equilibrium

$$(MP_N/MP_R)_C = (MP_N/MP_R)_D = MC_R/MC_N = P_R/P_N$$

The marginal rates of substitution (the ratio of marginal productivities) between R and N in the production of C and D must be equal to each other and to the marginal rates of transformation (relative cost) between R and N.

Note that the optimal point $E_{US}$ is an internal point (i.e, it meets all the marginal conditions for optimality) with a higher

[16]In developing the model in this section I have benefited from comments by Arthur Alexander, although the model does not correspond in all aspects to the one he suggested.

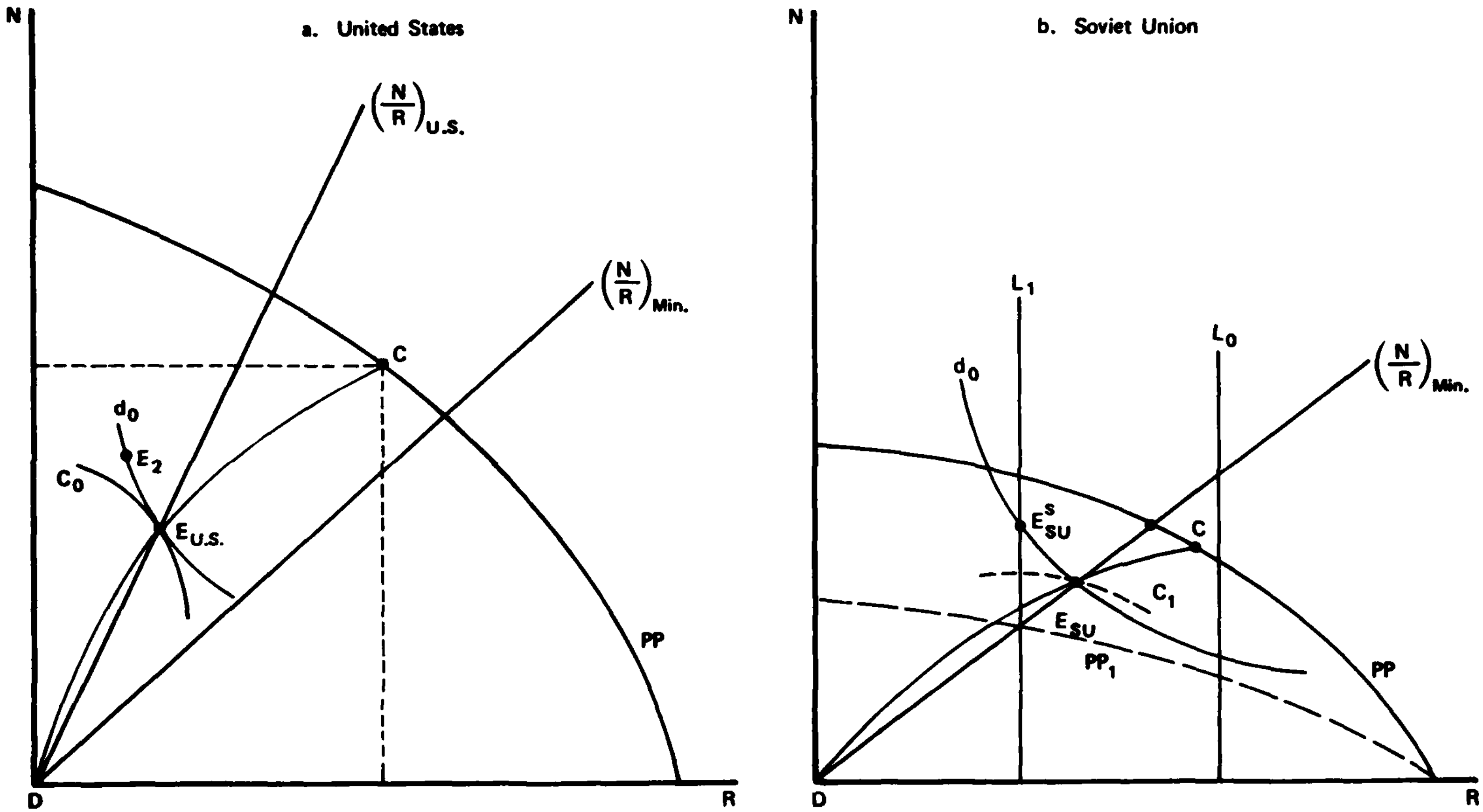


Fig. 2—Production possibility curves using innovation and routine inputs; defense and civilian sectors for the United States and Soviet Union

proportion of N than the minimum required. Also, the contract curve indicates a higher proportion of N in defense uses than in civilian ones.

Assume now that the Soviet Union produces the same amount of defense ($d_0$) as the United States and that the defense production function is also identical to that of the United States.[17] Thus $d_0$ and $(V/R)_{min}$ are replicated in Fig. 2(b) for the Soviet Union.

The main source of difference between the two countries is that the Soviet production possibility curve between R and N is much flatter, indicating the higher relative costs of producing N at each ratio of N/R. In Fig. 2(b) the Soviet case is drawn with *priorities*, so that even point $E_{SU}$, the least N intensive feasible point on $d_0$, is attainable only as a corner solution. At $E_{SU}$ the relative cost of producing priority treated MR&D is still higher than the marginal rate of substitution between N and R in the production of defense. For the sake of the argument here we do not need such an extreme case: $E_{SU}$ may be an internal rather than a corner solution and indeed the actual point can be to the left of $E_{SU}$, as long as it stays to the right of $E_{US}$ (at a lower N/R ratio). Later I show that $E_{SU}$ is unattainable without priority treatment.

There are two important results from the presentation so far: First, the Soviet Union should use a lower proportion of N in its military (and civilian) production than the United States. If this is indeed the case, it implies that both countries behave in the direction of the optimum, at least in relation to each other. But the mere fact that the Soviet Union uses less N or the United States more does not imply by any means that the former is closer and the latter is further away from its optimum. When one praises the military in the Soviet Union for using high R proportions in its weapon development (simplicity and hereditary and evolutionary development, etc.--see Alexander, 1975, 1978a, 1978b), the praise should imply only that the Soviet developers are on the right side relative to the United States. Likewise, high N proportions in U.S. development do not automatically imply

[17] This assumption is discussed below.

suboptimal behavior. The second result that follows from this point is that it is meaningless to compare the efficiency of the MR&D sectors of the two countries on the basis of defense output per unit of R&D input. A unit of Soviet defense output is produced with less R&D and more conventional inputs than the American; (the term "less R&D" is meant, of course, in the output rather than input sense of the term). This would be as incorrect as attributing a higher level of labor productivity to better labor performance when it results from higher ratio of capital to labor.

So far we have assumed that the production function of defense is identical in the Soviet Union and the United States, and this of course need not be the case. Specifically there are references in the literature to differences in tastes between the two schools of strategy (Alexander 1975, pp. 9-10, Alexander 1978b, p. 32). Taste may not be the right term but differences in "military doctrine" are possible and may indeed exist. If Soviet strategists believe that at any ratio of N/R the marginal productivity of R is higher than what the Americans believe, then the Soviet $d_0$ isoquant will be steeper and less N will be used even if its relative price (to that of R) is the same in the Soviet Union as in the United States (Fig. 3). The problem that still exists is to what extent declarations or pronouncements on doctrine are independent of the knowledge about feasibilities and relative prices. In an extreme case a doctrine may reflect different points on the same isoquant, points that were selected as optimal solutions for existing conditions. In view of existing differences in relative N/R costs between the two powers, one should wonder to what extent the military doctrines of both reflect ex-ante preferences or ex-post solutions (see Alexander, 1976, pp. 9-10). Economists as a group would probably lean toward the latter.

Differences in doctrine may result from differences in the set of objective requirements that make up defense. It is plausible that the Soviet Union as a land power needs a higher proportion of land forces in its defense than the United States, which is protected by oceans. If the proportions of N/R in the production of the different components of defense are different, then $d_0$ may be different too. Other things

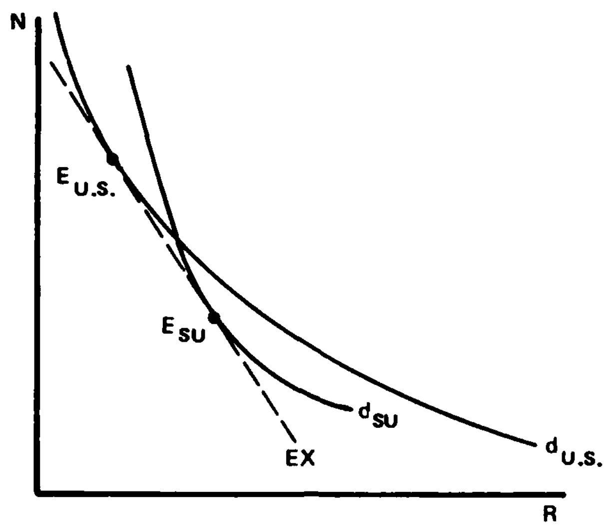


**Fig. 3—Defense production isoquants and relative prices, United States and Soviet Union**

being equal, more land forces--as the Soviet Union has--may mean a lower proportion of N. As with doctrinal differences, here too one has to be aware of the possibility that structural decisions are also made on the basis of information on relative costs.

Finally, the production function of defense may involve additional inputs whose production relations with N and R may affect the slope of $d_0$. Such a third factor may be military manpower. If it is more expensive in one country and at the same time more easily substituted for by N than by R, then $d_0$ will be flatter for this country. Or if in one country defense personnel find it easier or preferable to use R equipment rather than N, $d_0$ of this country will be steeper. There are references in the literature that the first description fits the United States and the second the Soviet Union (Holzman, 1979, p. 13).

Even if the relative price $P_N/P_R$ is equal in the United States and the Soviet Union (Figure 3, line EX) the Soviet Union may produce the same amount of defense as the United States ($d_{US} = d_{SU}$) with a lower N/R ratio (at $E_{SU}$) because of differences in doctrine, defense needs, or complementarity with other inputs.

The last three factors are possible reasons--other than relative prices--why the Soviet defense production function may cal' for a less

N intensive defense basket (See Fig. 3). Provided that these factors are independent of cost considerations, they may complement the cost considerations advanced here, and thus further reduce the N/R ratio in defense, or be a competing explanation: The observed lower N/R ratio may not result from high costs of N but from the above considerations. I believe in the former. But even if the latter is closer to the truth (with the sole exception of doctrinal differences where one may be right and the other wrong), a lower N/R ratio is called for in the Soviet Union on the basis of objective considerations, and Soviet-U.S. differences can both be in the right direction: toward the optimum. Furthermore, even if the other objective differences dominate, the estimation of MR&D efficiency by the ratio of defense to MR&D output is as wrong as before.

One question that still remains unanswered is how far each country is from its own optimum. With respect to the United States there are claims that as a result of pressures from scientists, engineers, and profit-motivated producers operating on the basis of cost plus, the proportion of N is too high, like point $E_2$ in Fig. 2(a). Excessive technology takes the form of gadgetry or a tendency to develop completely new systems when only marginal improvements are called for. In both cases the results are high costs for little results. There are many claims of this sort with respect to the United States and no doubt there is some truth in them (Alexander, 1976, pp. 3-8, 134-135). To the extent that this phenomenon exits, it increases Soviet relative efficiency in weapon development, and the voices that call for a more selective process in embarking on the development of new systems in the United States should be heeded. Anyone who tries to estimate the extent of this bias should take into account that the United States should be more technologically intensive than the Soviet Union, and Soviet behavior is not the norm for the United States. Finally, even some of the critics of United States policies restrict their criticism to the wholesale approach and agree that the innovation-intensive approach is advantageous to the United States with respect to essential weapon systems. There may have been overinnovation in the development of tanks but not in airplanes, strategic weapons, etc. (Alexander, 1976, p. 134).

To see whether the Soviet Union is at its optimum point, $E_{SU}$, we have to examine this point in the context of the priority system and other constraints. Without priority treatment, point $E_{SU}$ in Fig. 2(b) is unattainable. One way to demonstrate this claim is to draw the Soviet production possibility curve before priorities as $PP_1$. This implies that the introduction of priorities (shift to PP) is an organizational improvement that allows the system to have more N and R, at least along a certain range. An alternative possibility is that without priority the Soviet Union is physically unable to move leftward to $E_{SU}$, and only priority treatment opens up those parts of PP necessary to achieve $d_0$. Such a constraint without priorities is indicated by $L_0$ in Fig. 2(b). When priorities are applied, $L_0$ is shifted to $L_1$. In reality there are probably elements of both possibilities.

It is important to emphasize that at point $E_{SU}$ the ratios of *shadow* marginal productivities of N to R in defense and civilian production are *equal*. Planners in Gosplan do see the actual true price of priorities and account for them correctly where they belong. Even at this optimal point, military production uses a more N intensive ratio than does civilian production.

It was pointed out earlier that bureaucratic conservatism and unfocused incentives push the actual point to the right of the optimum--to less N intensive proportions. If this is the case in defense, too, then the priority treatment must push the L constraint further to the left or PP further upward so as to make $E_{SU}$ the optimum point of the individual managers in both the military and civilian sectors. Here, however, comes another effect of the priority treatment favorable to MR&D: As we have seen before, some of the priority related costs are not charged to MR&D and are indeed charged to or borne by civilian users. The effect is on the one hand to narrow the gap between the private and public optimum points in the MR&D sector, where artificially lower costs compensate for difficulties unaccounted for by the center, and on the other hand to widen the gap between social and private optimum points in CR&D. Thus, if MR&D is closer to the desired social optimum point, it is again with a higher N/R ratio than the civilian sector. Still, there is a possibility that MR&D will have a too low N/R ratio

in defense because of the stronger effect of conservatism and a bureaucratic approach to innovation. If this is the case then $E^S_{SU}$ is the socially optimal point and $E_{SU}$ is the position actually achieved because of the net effect of conservatism. The civilian isoquant *intersects* the military one at $E_{SU}$; this presents the rate of substitution between N and R equal to $P_R/P_N$ as seen by individual managers.

Under such circumstances--when $E_{SU}$ is too routine intensive--some degree of genuine technological bias (but not goldplating) might have a positive effect as long as the actual point is not pushed beyond $E_{SU}$. It is, however, commonly claimed that excessive goldplating is prevented in the military sector by a more effective budget constraint than in the civilian sector--that the military sector economizes on R&D more than does the civilian sector. The new evidence on the true size of the Soviet military budget makes it less likely that MR&D suffers more from a budgetary pinch than, let us say, its civilian counterpart.[18] There are new pronouncements and pieces of evidence that the military "has funds" (Agursky and Adomeit, 1977, pp. 18, 58; Perakh, 1976, and others). If indeed a suboptimal technological bias has to be blunted, it seems likely that in the military sector it is stopped simply by means of an inability to develop excessively N intensive weapon systems within the time limits that are dictated by outside competition.[19] Such time and capability constraints are represented in Fig. 2(b) by the vertical line $L_1$, which I have drawn at $E^S_{SU}$.

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[18] There is apparently little new information as to how to update the Soviet MR&D costs, but the nature of the updating process points to the need for even larger corrections in Western estimates of these costs.

[19] See Alexander, 1978b, pp. 18, 21, 30, Nimitz, 1971, pp. 44-45, Vladimirov, 1973, p. 61, Holzman, 1979, pp. 11-12, including citations from Turner and Colby.

## VI. CONCLUSION

The relative efficiency of Soviet MR&D is probably much lower than appears from the paradox presented at the outset or in the view of some students in the field, on two counts: First, the real burden or cost of MR&D is much higher than conventionally estimated; second, the total output of MR&D is lower than previously assumed. When inputs are higher and outputs are lower, estimated efficiency goes down. These two counts are translated to the Soviet-American comparisons by way of Fig. 2: On one side the Soviet production possibility curve between innovation and routine production is much flatter than the American, even with priorities; on the other side the Soviet proportion of N in the production of defense is lower. Both factors are not enough to prove that the relative efficiency of Soviet MR&D is lower than that of the United States. It significantly narrows the apparent or claimed Soviet advantage in this field. The second part of the argument, that a lower proportion of N is not in itself a sign of higher efficiency (and that "efficiency" is wrongly calculated), was not found in any previous work.

The main controversy centers on the first part of the argument. Observers disagree as to whether some of the advantages enjoyed by MR&D are "natural," "untransferable" and thus costless, or policy-determined and thus both costly and at least in principle transferable to other sectors of the economy. Many of these policy-determined advantages are part of the extensive priority system, which should not be understood narrowly as "resource priority" only but also as extending to affect structure, procedures, power, and even morale of MR&D operations. The significance of the effect of priorities beyond resources is another source of disagreement.[20] Other disagreements relate to the direction of the effects of some natural advantages--notably outside competition.

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[20] These reformulations are based on alternative maps of causality offered by Arthur Alexander.

It was pointed out above that the preferential treatment of MR&D is transferable in *principle* to other sectors of the economy. Transferability is a key issue because it determines in part whether priorities consist of alternative costs to other sectors. A number of conclusions on the transferability of MR&D capabilities to the CR&D sectors emerge from the analysis. First, a mere shift of budgets will not do the job: R&D requires many inputs and arrangements that even money cannot buy in a Soviet type of system. Second, it would be self-defeating to effect a transfer by spreading the priority treatment of the military to the entire R&D sector and to the industries it supports. Because priorities must be restricted to be effective, such a transfer would lead to a great loss in the efficiency of MR&D and little gain to CR&D.

The one form of transfer that could be effective under the present system would be along the "mission oriented" approach or through "innovation by order" (see Berliner, 1976, pp. 504-510)--that is, to extend to a well-defined, fairly small civilian sector the kind of priority treatment enjoyed today by the military and so concentrate on this sector some of the most important CR&D efforts. Such a sector could be a number of important segments of the machine-building industry, such as automobiles, argicultural machinery, drilling and transport machinery for oil and gas exploration, chemical machinery, electronic equipment, and the like. Government agencies could bypass the complicated economic criteria and specify technical requirements for the major items to be developed, probably on the basis of existing Western equipment, and create a "military environment" in all aspects of supply, demand, and organization as described in this report. Although such a civilian sector would lack some of the natural advantages of military activity, it would profit considerably from being able to copy many Western techniques and also from not having to reach quite the technological level required in the military sphere. The organization of the Soviet economy, although not its tradition, is almost ideally suited for such a transfer, and I do not see any *theoretical* reason why it should not work.

It is the characteristic of lumpiness that makes the solution unlikely to happen in practice. The long history of directing priorities

to the military sector also adds to the actual difficulties of transfer practice. The lumpiness is not absolute, however, and with some difficulties one may transfer priorities from some military sub-sectors or projects to civilian ones of approximately the same size. Even such partial transfers may have significant importance to the civilian sector and may feature as a policy variable in the considerations of the leadership. But even in the unlikely event of a total shift, the problem of R&D in the Soviet system will not be solved; the difficulties are systemic and priorities can cover only a narrow range. It is this condition as well as the lumpiness mentioned above that pushes the Soviet leadership to look for solutions to the CR&D sector in different directions, by adopting internal reforms and importing technology (with monies earned in part from exported arms). If the analysis in this report is valid, these are stop-gap solutions and cannot provide a lasting answer.

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